# FindSources3D - Source Localization Using Rational Approximation on Plane Sections

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Todor Jordanov[1], Jean-Paul Marmorat[2], Maureen Clerc[3], Juliette Leblond[3], Andre Waelkens[1], Theodore Papadopoulo[3]

1 BESA GmbH, Gräfelfing, Germany

2 Ecole des Mines ParisTech, Sophia Antipolis, France

3 INRIA, Sophia Antipolis, France


## I INTRODUCTION

A new method for EEG source localization based on rational approximation techniques in the complex plane [2] was suggested. The method is used in the context of a nested sphere head model, in combination with a cortical mapping procedure. This method was shown to perform perfectly for numerical simulations without noise but its performance with respect to different signal-to-noise ratios (SNRs), to different number of sources and to real EEG data was not investigated until now. The method, formally called FindSource3D (FS3D)[3], is evaluated here with data simulations and a real EEG data set.

## II MATERIALS and METHODS

### *FindSource3D*

FS3D makes use of a spherical head model made of consecutive layers (scalp, skull, brain) of constant conductivity.

The algorithm of FS3D consists of two main steps - data transmission and source recovery (Figure 1).

1. Data transmission from the scalp to the cortex involves the following.

1.1. Cortical mapping - The data are transmitted from the surface of the scalp where it is measured onto the surface of the brain [1].

1.2. Harmonic projection - Filtering out possible outer sources by keeping only the information related to the effective inner sources in the brain.

2. Source recovery in the brain from data on the cortical surface involves the following.

2.1. Plane sections - The sphere modeling the cortical surface is sliced along families of parallel planes yielding disks inside which the singularities will be sought. The 2D singularities form within the sphere a family of lines intersecting at the position of the 3D sources.

2.2. Planar singularity detection - 2D approximation techniques are used to find the planar singularities on the plane sections of the brain, approximated by poles of rational functions.

2.3. 3D source localization - For a putative number of sources, the sources are localized in 3D by analyzing the sets of planar singularities.

2.4. In order to fine-tune the resulting source estimation an additional dipole fit algorithm with constrained source movement range was applied.

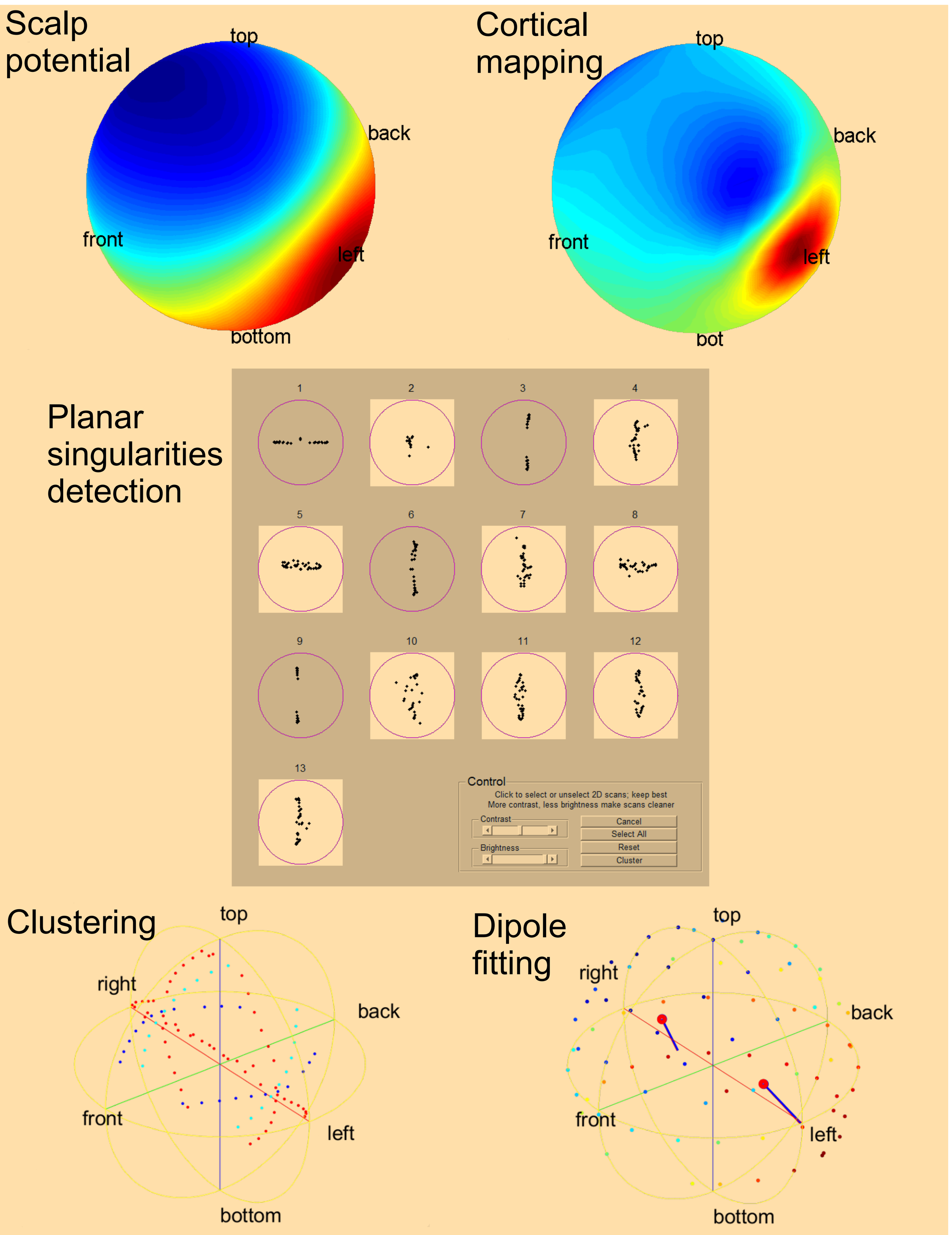


**Fig. 1** Typical workflow of FS3D: i) scalp potential map, ii) cortical mapping, iii) planar singularity detection, iv) clustering of the planar singularities and v) dipole fitting.

### *Simulations*

In order to investigate the performance of FS3D various EEG data with 81 standard electrodes were simulated: (1) single deep source, (2) single superficial source, (3) bilateral temporal sources, (4) three sources - in the medial frontal gyrus, left and right insula. Additionally, the bilateral temporal activity was altered by adding different noise levels to the sensors, thus yielding data with 19 different SNRs between 2 and 20.

### *Real EEG Data*

Tones of 5 intensities (60, 70, 80, 90, 100 dB sound pressure level) were presented binaurally in pseudorandomized form. Evoked potentials were recorded with 32 electrodes referenced to Cz and sampling rate 250 Hz. For the source reconstruction with FS3D the 60 dB condition, latency = 88 ms, was used. After artifact rejection 64 trials were accepted for averaging.

## III RESULTS

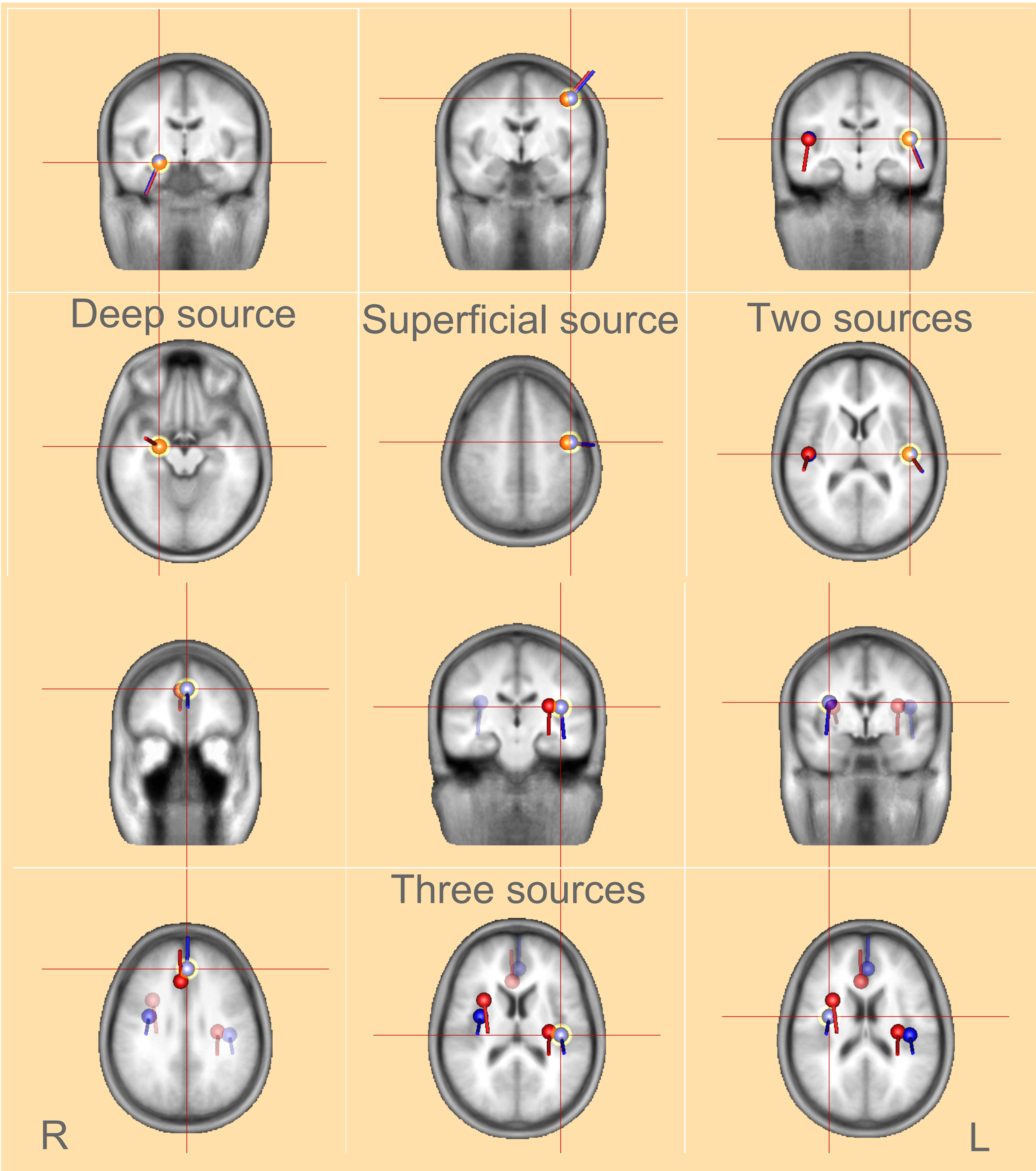


**Fig. 2** Performance of FS3D for simulations without noise. Blue dipoles mark the simulated sources, red dipoles - sources reconstructed by FS3D.

### *Simulations without noise*

The reconstruction with FS3D for the simulated data without noise yielded the following results: for the dipole in the right amygdala the distance between the simulated and the estimated source was 0.6 mm, for the left primary motor cortex - 3.4 mm, for the bilateral temporal case - 0.3 mm right and 0.5 mm left, for the three sources case - 10.7 mm left, 15.2 mm right and 12.4 mm frontal source (Figure 2).

### *Simulations with different SNRs*

The simulations with different SNRs revealed a negative linear trend in the relation between SNR and distance to the simulated sources (Figure 3).

### *Real EEG data*

In the case of real EEG data the sources estimated by FS3D are located bilateral in the medial end of the left and right Heschl's gyrus (Figure 4).

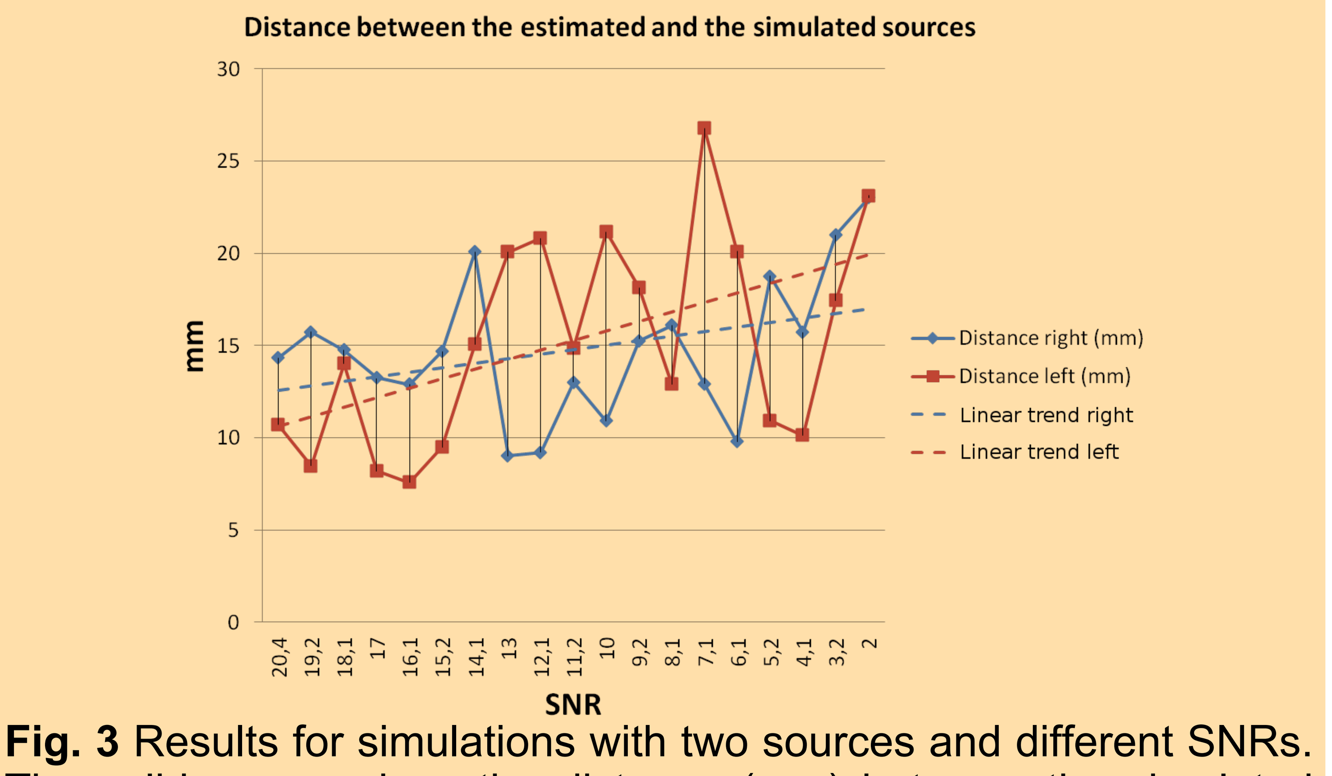


**Fig. 3** Results for simulations with two sources and different SNRs. The solid curves show the distance (mm) between the simulated and the estimate sources. The dashed lines show the corresponding linear trends.

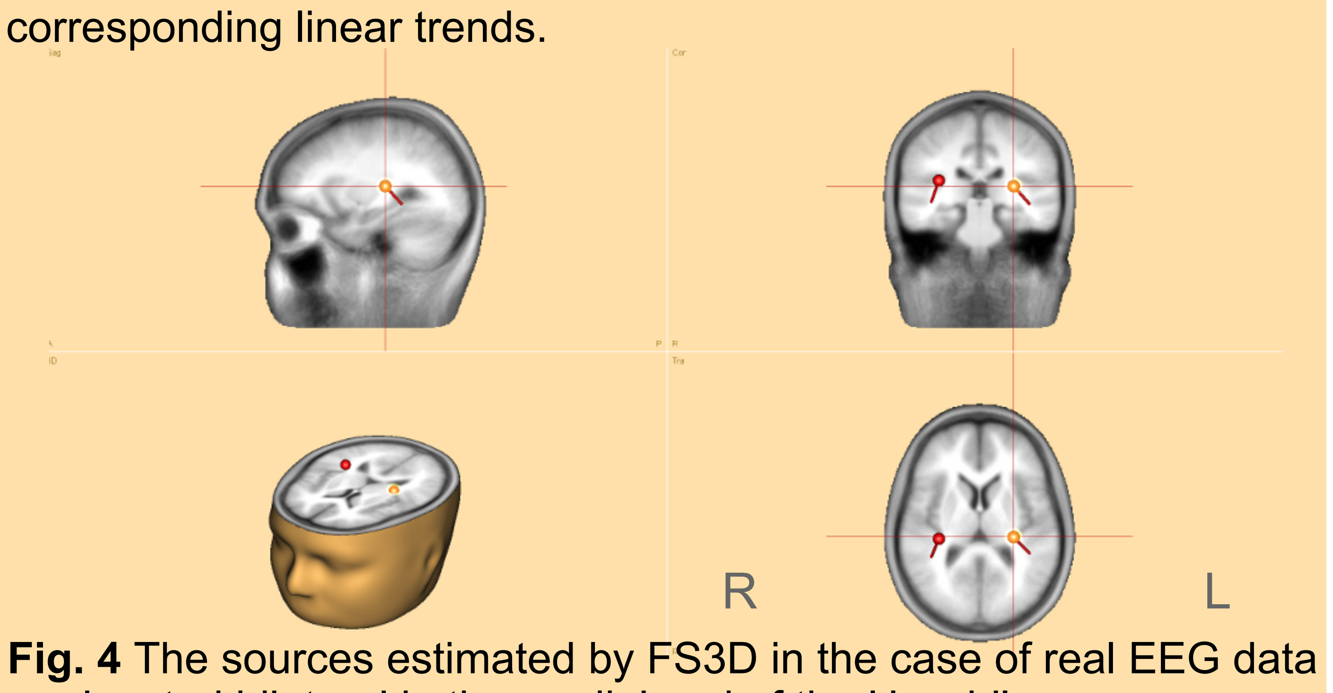


**Fig. 4** The sources estimated by FS3D in the case of real EEG data are located bilateral in the medial end of the Heschl's gyrus.

## IV CONCLUSION

FS3D was able to reconstruct perfectly the simulated brain activity without noise up to two sources. In the case of three sources the estimated dipoles did not match the simulated exactly but the results could still be considered reliable. The performance of FS3D decreases with increasing of the noise level as expected, however, the estimated localizations remain adjacent to the simulated even for the lowest SNR. Finally, FS3D was able to reconstruct correctly the auditory evoked responses in real EEG data.


[1] Clerc, M., Kybic, J., 2007. Cortical mapping by Laplace–Cauchy transmission using a boundary element method. Inverse Probl. 23, 2589.
[2] Clerc, M., Leblond, J., Marmorat, J.-P., Papadopoulo, T., 2012. Source localization using rational approximation on plane sections. Inverse Probl. 28, 055018.
[3] http://www-sop.inria.fr/apics/FindSources3D/en/



Corresponding author:

Todor Jordanov (todor.jordanov@besa.de)
Gräfelfing, Germany